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# Request for grant of a patent

*(See the notes on the back of this form. You can also get an explanatory leaflet from the Patent Office to help you fill in this form)*

**The Patent Office**

Cardiff Road
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| | | |
|---|---|---|
| 1. Your reference | CPH/2 | |
| 2. Patent application number *(The Patent Office will fill in this part)* | 0227628.5 | 27 NOV 2002 |
| 3. Full name, address and postcode of the or of each applicant *(underline all surnames)* | Dr. Christopher Paul HANCOCK<br>61 Bryants Hill<br>St. George<br>Bristol<br>BS5 8QZ<br>United Kingdom | |
| Patents ADP number *(if you know it)* | 8314598001 | |
| If the applicant is a corporate body, give the country/state of its incorporation | | |
| 4. Title of the invention | Miniature Monopole Antenna Structures for Minimally Invasive Therapeutic Cancer Treatment and use in Intricate Open Surgery Procedures | |
| 5. Name of your agent *(if you have one)* | | |
| "Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)* | | |
| Patents ADP number *(if you know it)* | | |

| | Country | Priority application number *(if you know it)* | Date of filing *(day / month / year)* |
|---|---|---|---|
| 6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number | | | |

| | Number of earlier application | Date of filing *(day / month / year)* |
|---|---|---|
| 7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application | | |

| | |
|---|---|
| 8. Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:*<br>*a) any applicant named in part 3 is not an inventor, or*<br>*b) there is an inventor who is not named as an applicant, or*<br>*c) any named applicant is a corporate body.*<br>*See note (d))* | YES |

# Miniature Monopole Antenna Structures for Minimally Invasive Therapeutic Cancer Treatment and use in Intricate Open Surgery Procedures

## Invention:

This patent addresses the use of miniature co-axial structures for minimally invasive treatment of breast cancer, brain tumours and other cancerous growths where small probe structures lend themselves to well controlled localised therapeutic treatment. The use in other open surgery procedures is also briefly addressed.

Fine co-axial structures and a controlled microwave energy source are considered since these ensure localised treatment, with a predictable temperature profile within the tissue.

## Overview:

The general instrument structure is shown in figure 1, where it can be seen to consist of a basic coaxial structure, with a number of quarter wave (or multiples thereof) short-to-open converters (baluns) to prevent current from flowing down the outer sheath. Figure two shows the range of outside diameters that we are considering and a possible embodiment that uses a very thin layer of dielectric material (could be a spray) and a thin outer copper layer to form the second co-axial structure for sheath current reduction.

The energy source is proprietary to this work and uses latest state of the art semiconductor power devices to provide the necessary power at the distal end of the electrode in a controlled manner. One possible embodiment of the microwave generator is shown in figure 3 and operates in the frequency range of between 14GHz and 15GHz. The said instruments will be designed to efficiently power match into the load impedance, but be a very poor radiator into the impedance of free space or surrounding objects. This is achieved using our dynamic impedance matching system, which is also proprietary to this work.

## General:

Micro-miniature instruments will be co-axial structures where it's possible to achieve an overall outside diameter of less than 1mm. Thus making it feasible to carry out very intricate precision treatment on delicate organs, such as the brain and throat, where it is paramount that the energy source does not affect surrounding tissue. Such instruments could also be used in open-heart surgical procedures where fast coagulation would be very useful. Although this is outside of the scope of the work documented here, It should still be noted here that such instruments could be used as an aid in general surgery where lower acceptable Industrial Scientific Medical (ISM) frequencies, such as 5.2GHz and 2.5GHz, could be adopted.

The general instrument structure is shown in figure 1, where it can be seen to consist of a center conductor and an outer return conductor, made from either copper or silver, with a low loss dielectric material separating the two. The characteristic impedance of the structure is determined by the ratio of the inner diameter of the outer conductor to the outer diameter of the inner conductor and the permittivity of the dielectric material. The structures to be considered initially in this work will have an impedance of 50Ω, but other more geometrically manageable impedances may be chosen where either quarter wavelength transformers are used or the length of the structures are exact multiples of half wavelength at the frequency of operation. The dielectric material used must have a very low loss factor (low $\tan\partial$) at frequencies in the range: 14GHz to 14.5GHz (or other chosen frequency) in order to minimise electrode heating and insertion loss through the instrument. If the magnitude of sheath current, which flows along the outer conductor, is high enough to be felt by the user, then a number of quarter wavelength short-circuit to open-circuit baluns can be placed along the outer conductor. These sheath currents can cause burns and so they should be prevented at all cost.

If impedance transformations are required at the instrument end, then this can be easily realised using quarter wavelength co-axial sections of suitable impedance. The connectors can either be N-type, K-type, or SMA (SMB or SMC may also be considered). For input power levels of 46dBm (40W) or greater N-type should be used. Other terminations may need to be considered for very small diameter instruments. Several semi rigid-cables with diameters that gradually reduce could also be considered, or, perhaps, the recently introduced miniature microwave connector set may be a solution for low power levels. Very small co-axial structures allow only a pure TEM wave to propagate even at the high frequencies used here since the diameters considered are much less than half the guided wavelength.

One very interesting application of these instruments is to enable treatment of cancerous cells at a very early stage via keyhole surgery. In this case the outer diameter of the instrument will be less than 1mm (at powers of less than 5W, semi-rigid cables with an outside diameter of 0.5mm are available). It may be possible to terminate the end of the instrument with a pointed cone of high permittivity, low loss microwave ceramic material. This would concentrate the electric field distribution at the tip and allow fine tissue tunneling into the cancerous region. This construction would provide a very high energy density source that could be used to channel through an organ, i.e. the lung or breast, causing minimal damage. When the target area is reached, the power level could be increased to enable the cancerous tissue to be eradicated via a short burst of very higher energy radiation. The channel used to reach the cancerous site will be small enough such that the damage caused to healthy tissue heals quickly, causing the patient minimal stress. Figure 2 shows a possible construction for the instrument described here.

Larger diameter co-axial constructions can be considered, but it should be noted that when the diameter of the inside of the outer conductor becomes greater that a half wavelength of the EM wave, then other modes of propagation will occur which will provide constructive and destructive

interference to the main signal, making it more difficult to control the tissue effect. However, if the modes could be launched in a controlled manner then this may lead to some interesting tissue effects in terms of the variation in depth of penetration due to the various E and H fields being radiated. There would also be a modal variation in power level. The study of the variation in depth of penetration into various tissue structures as a function of mode would be a very interesting phenomena to study.

Claims:

1. Micro-miniature co-axial instruments can be used to produce very high energy densities at the tip of the instrument .

2. Micro-miniature co-axial instruments allow the energy to be focused and minimizes effects to surrounding healthy tissue.

3. Micro-miniature co-axial instruments allow precision procedures to be carried out on delicate organs, such as the brain, throat and the heart.

4. Physically long micro-miniature co-axial instruments, constructed to have a very low insertion loss, can be used in minimal access surgery where ongoing treatment is necessary. In which case, the system could easily lend itself to outpatient surgery.

5. Slightly larger co-axial based instruments can support modes of EM field propagation other than the pure TEM mode to yield interesting tissue effects. It has already been shown that for a rectangular waveguide, the $TE_{30}$ mode can be used to give a more uniform tissue effect than that obtained by simply propagating the dominant $TE_{10}$ mode.

6. The co-axial structures considered in this work will use fully enclosed copper/silver outer conductors and may also include BALUNS to minimise any sheath currents that flow back along the outer conductor. These instruments, therefore, present minimal risk to the patient or surgeon in terms of damage caused by un-focused radiation (or UHF burns).

7. The distal end of the micro-structure co-axial structures may be terminated with a very high permittivity microwave dielectric in order to concentrate the E-field in the region of the instrument tip, which is desirable for fast precise tissue tunneling.

8. A further application of the micro-miniature co-axial structures is where the cancerous growths form at inaccessible sites, such as the inside of a lung or breast. . In this case the use of a structure with an outside diameter of less than 1mm is envisaged, this will minimize the damage to healthy tissue on the way in; also by making a very small tunnel the patient recovery time is improved. A high permittivity microwave ceramic cone could be used at the tip of the instrument to concentrate the E –field, thus speeding up the incision rate. The power (energy) will be initially set to enable tunneling to the treatment site to be dominantly caused by the radiation transport mechanism. Once the cancerous site has been located, the energy will be adjusted to enable the fast eradication of the cancerous cells. This again may be achieved using radiation as the dominant energy transport mechanism.

9. A further application of the micro-miniature co-axial structures is in open-heart surgery, where very small and fine instruments that deliver energy at high UHF frequencies could be used to effectively cut and rapidly coagulate intricate tissue structures such as those found in the heart. The fast co-agulation would immediately prevent bleeding thus enhance possible precision available to the surgeon.

10. Where micro-miniature co-axial instruments are used whose outside diameters are less that 1mm, the energy density at the tip of the instrument may be so high that very small power levels, i.e. 5W, may be sufficient to cause the desired tissue effects. If this is the case then very lightweight cable assemblies can be considered which would be helpful when fine precision procedures are being carried out.

11. The use of such high frequencies (14GHz to 14.5GHz)enables high radiated energy levels with small wavelengths to be produced at the distal end of the instruments.

12. A major application for such a system could be for the treatment of breast cancer. The therapeutic microwave energy will instantly ablate the lesion and leave surrounding tissue untouched. The micro-miniature co-axial structures aids probing to be carried out whilst causing minimal damage to healthy tissue.

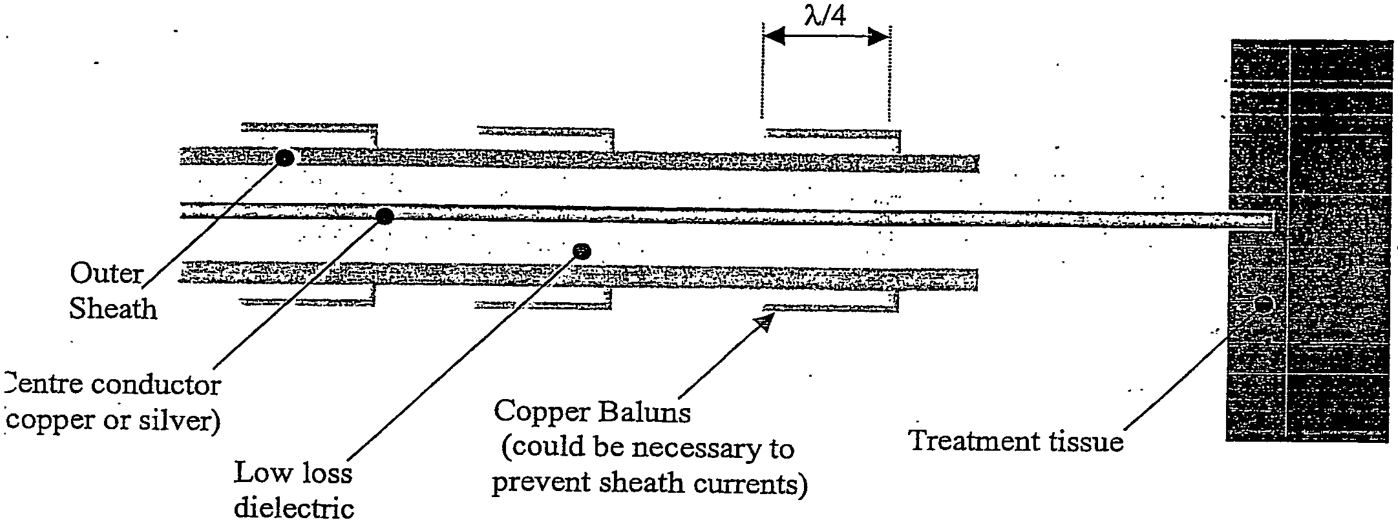
13. For the micro-miniature co-axial instruments, $\lambda/4$ baluns could be constructed using low loss dielectric spray coatings (or thin tape, such as poliamide) combined with thin beryllium copper (or copper tape) in order to increase the overall diameter of the electrode. It may also be possible to recess the short-circuit to open-circuit balun into the outer wall of the semi-rigid body; leaving the overall electrode diameter unaltered.

14. Feedback information from reflected power measurements can be used to determine the tissue impedance changes to indicate the state of the tissue during treatment. This information is in the form of a return loss power level provided by a reverse power coupler. This information can be used to control the source power level, i.e. back off the power when the impedance increases as this indicates that the tissue has been successfully ablated.

15. This feedback information will also be used to control the dynamic matching network when tunneling towards the cancerous site.

Figure 1: General Monopole Co-axial Structures

Inside side cross-section:




Possible structures and end variants:

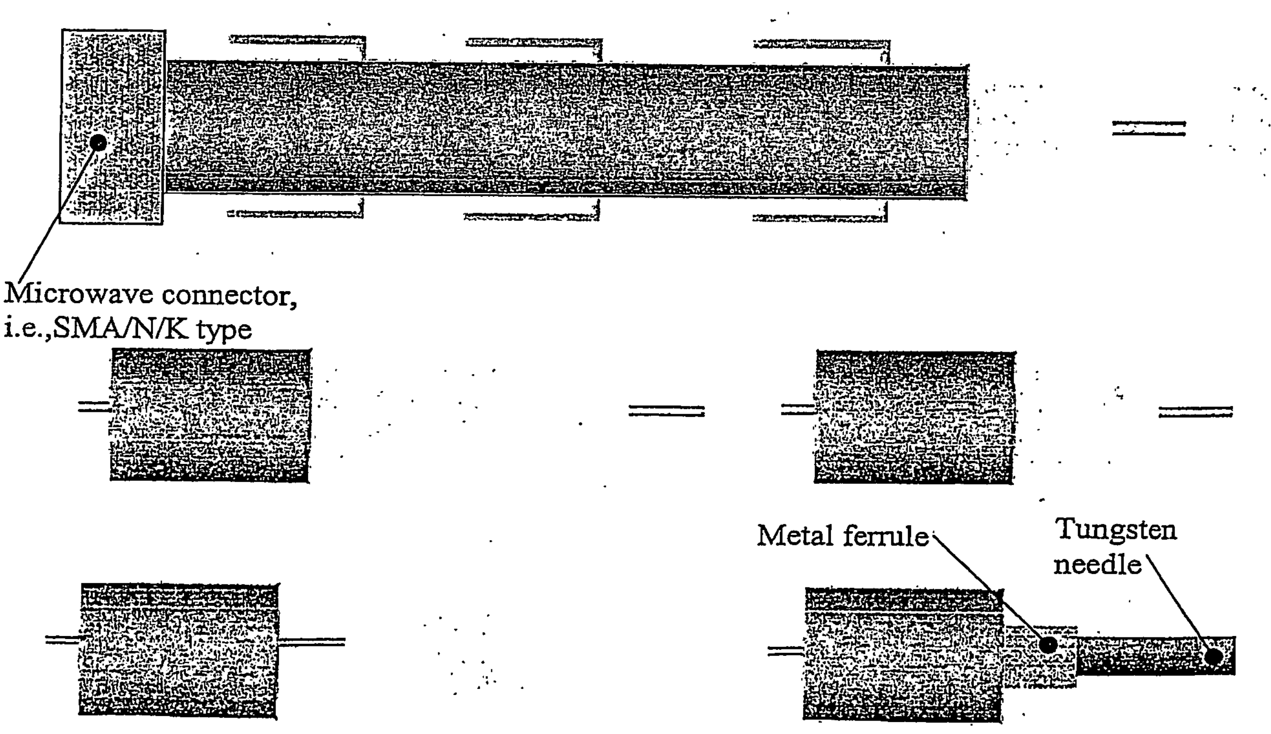
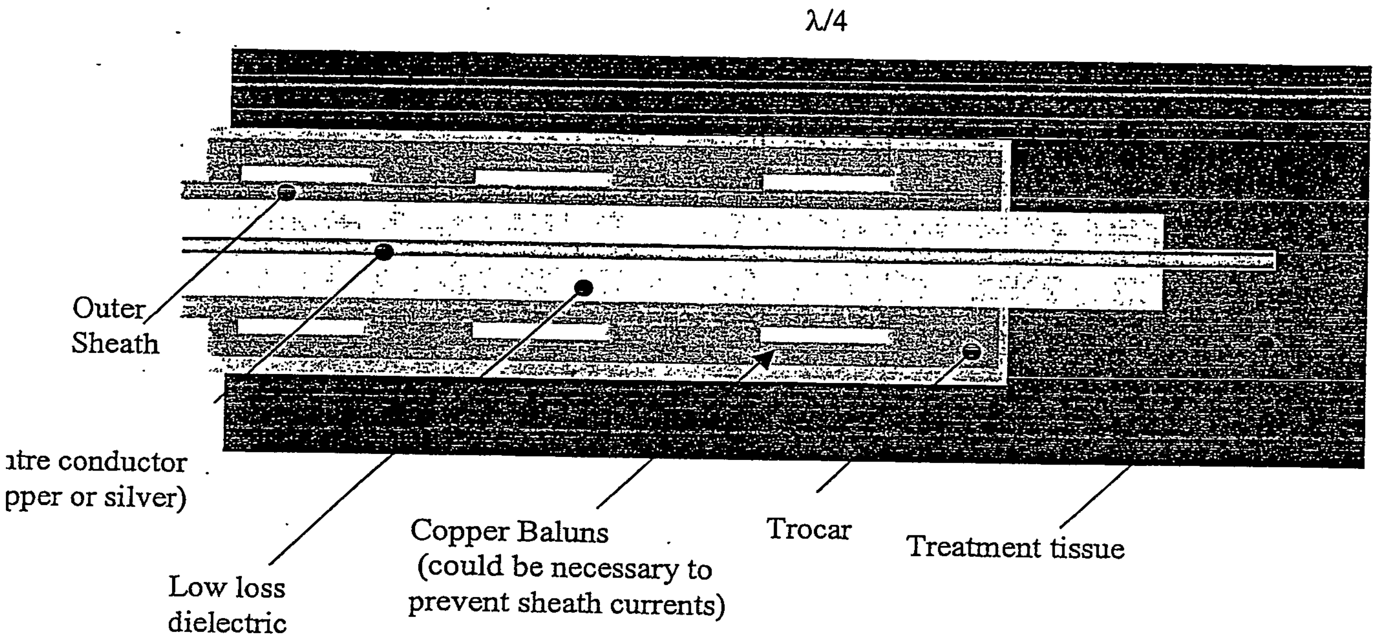
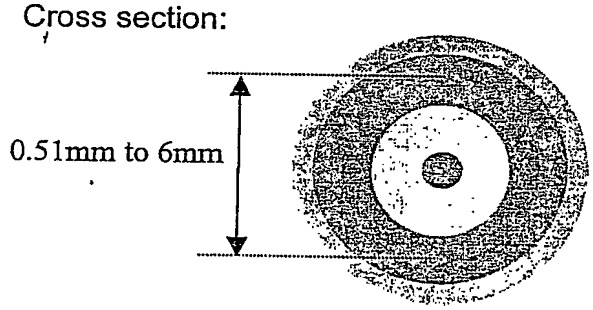


Figure 2: Keyhole treatment of small inaccessible sites using miniature co-axial instruments

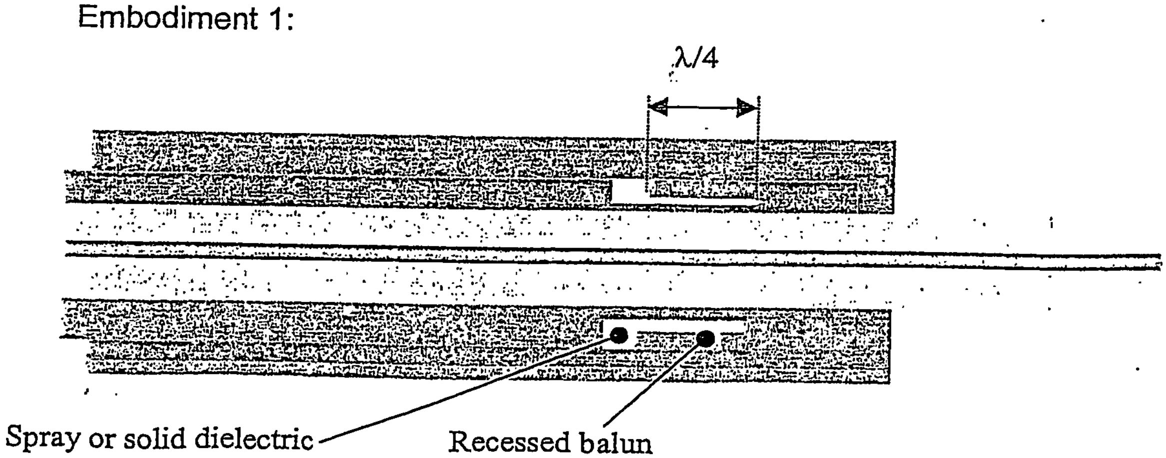
Basic instrument:




Cross section:




Embodiment 1:



<u>Figure 3:</u> Preferred Embodiment of Microwave Stages